

I. COMPARING INDUSTRY AND ACADEMIC PERSPECTIVES ON CROSS-DOCKING OPERATIONS

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Abstract

This paper performs a comparative analysis on the industry and academic perspectives on cross-docking operations. Detailed descriptions are provided for three typical cross-dock settings by means of case illustrations. The purpose of these descriptions is to inspire break-through innovations in future cross-docking research by identifying constraints, decision problems, and performance indicators that are thoroughly anchored in current practice.

1. Introduction

Many academic cross-docking papers propose mathematical models for the support of cross-docking design, planning and control decisions – see [3], [5], and [6] for reviews of the corresponding literature. The most notable lines of research therein focus on local cross-dock optimization and predominantly solve problems related to determining where (i.e., at which dock door) and when (i.e., in which sequence) trailers are to be served at the cross-dock. The state-of-the-art solution approaches for these decision problems have progressed by academic papers addressing gaps left by previous research. By explicitly positioning their work within these gaps, authors have convincingly demonstrated the *academic relevance* of recent cross-docking papers. The *industrial relevance* of the proclaimed advancements to the literature may not unequivocally stand up to empirical scrutiny. We note, for example, that recent papers have not derived fundamentally new problems from a thorough study of current cross-docking practice.

Having visited a wide range of cross-docks in Europe, we conclude that some typical cross-dock settings and frequently occurring management problems are not yet addressed

in the literature. In addition, we observed little application of the academic decision models in industry. By contrast, insights from the related field of warehousing research are frequently applied to contemporary warehouse management systems [8]. In this *paradigm paper* we aim to advance understanding about the differences between the industry and academic perspectives on cross-docking operations. Using case illustrations, the paper sets out descriptions for three typical cross-dock settings. The objective of this paper is to form a starting point for future innovations in cross-docking research by identifying constraints, decision problems, and performance indicators that are thoroughly anchored in current practice.

2. Research approach

In this paper we focus on the operational planning of cross-docking, with the cross-dock facility as focal point of study. Planning decisions made elsewhere in the distribution network, but directly affecting local cross-dock decision-making and performance, are also considered. Strategic decisions, concerned with, for example, distribution network and local cross-dock design aspects, are left outside the scope of this work.

The empirical foundation for the work in this paper stems from a decade of academic research we conducted in close collaboration with cross-docking practice. In this period, we visited over 25 cross-docks throughout Europe. Analyzing the range of different cross-docks visited, we recognize three typical cross-dock settings: Less-than-truckload (LTL) end-of-line terminals, LTL break-bulk terminals, and cross-dock terminals in the distribution network of large retailers. For each type, we performed one to three in-depth case studies. The case studies lasted for 4 months to 3 years during which the companies allowed unlimited access to historical operational data.

In this paper, we describe each of the three typical cross-dock settings according to the following aspects:

- The characteristics of inbound, internal, and outbound logistics processes.
- The main questions considered during the planning of cross-dock operations.
- The key performance indicators.

Subsequently, we compare the problem description for each cross-dock setting against the state-of-the-art decision models in cross-docking literature. Knowledge about this academic state-of-the-art is derived from our recent research classification [6]. The aim of comparing the academic and industry perspectives on cross-docking operations is to identify and describe several interesting new research themes that contribute to a better fit between those perspectives.

3. Cross-dock settings

This section describes each of the three typical cross-dock settings.

3.1 LTL end-of-line terminal

LTL end-of-line terminals are part of transportation networks, which are commonly organized as a hub-and-spokes system. An end-of-line terminal is used in performing fine-grained distribution activities, i.e., it serves the purpose of picking up and delivering loads from/to customer locations. Moreover, loads picked up for delivery by another terminal are flowing into the transportation network. Similarly, an end-of-line terminal receives loads for delivery that were picked up by another terminal. End-of-line terminal are often operated as a cross-dock.

The description of this typical cross-dock setting is based on three in-depth case studies at road-freight carriers in The Netherlands.

3.1.1 Description of logistics processes

In an *LTL end-of-line terminal* cross-dock setting, the planning of inbound and outbound logistics processes at the cross-dock is the result of route planning decisions made by a centralized planning department. That is, based on time-window restrictions specified by a large number of customers, the planners construct vehicle routes such that pickup and delivery locations for loads are efficiently serviced. Vehicle routes may re-direct loads to the cross-dock to enable consolidation of small-sized shipments. Hence, the constructed vehicle routes dictate the arrival and departure times for trucks at the cross-dock – as well as their load composition. From the perspective of the cross-dock manager, the corresponding load compositions and arrival/departure times of trucks are given.

Inside the cross-dock, the cross-dock manager allocates one or multiple material handlers to the unloading of shipments from an inbound trailer. Upon unloading, all shipments are placed in a staging area directly behind the dock door. Subsequently, the inbound trailer load is checked for damaged shipments and missing labels (using an unloading list) and each shipment is scanned – so that its arrival is known. After checking the complete inbound load, material handlers are allocated to the movement of shipments through the cross-dock. In the case the outbound trailer of a particular shipment is known upon arrival – and that trailer is already docked – the shipment can be directly moved to the outbound dock. Often, however, the outbound trailer of a shipment is not yet known upon its arrival. In that case, the shipment is placed in a staging area based on the ZIP code of its destination. Once an outbound trailer is docked, one or multiple material handlers are allocated to load that trailer. As will be explained in more detail below, the process of loading outbound trailers differs according to the type of outbound trailer. Typically, (teams of) material handlers are dedicated to perform a certain task, i.e., either unloading, scanning/checking, moving, or loading.

The freight flows of an LTL end-of-line terminal are characterized by two types of inbound/outbound trailers, which differ with regard to fixed loading sequence and loading deadlines. The first type of trailers are operated on local collection and delivery routes. Inbound trailers of this type (i.e., carrying loads that were picked up at customer locations) arrive throughout the day – with a peak around the end of the afternoon and early evening. Outbound trailers of this type (i.e., carrying loads that are to be delivered at customer locations) mostly depart early the next morning. Hence, the deadlines for loading such outbound trailers are not tight. Due to the many stops on the delivery route, with a known sequence, the loading sequence of the outbound trailers is important. The second type of trailers are operated on line-haul routes, i.e., connecting the terminal with other terminals in the network. In order to enable short delivery lead-times in the network, the line-hauls are often operated overnight. Hence, the deadlines for loading such outbound trailers are tight. The routes are characterized by a limited number of stops. Often, a line-haul trailer shuttles between two terminals. Accordingly, the loading sequence of the outbound trailers is not important. Due to the relatively long transportation distances between terminals, the trailers have to be fully loaded, which typically takes more time.

3.1.2 Central managerial questions

One of the key decisions when managing *end-of-line terminal* cross-dock operations is the allocation of material handlers to the tasks to be performed. In making these resource allocation decisions, the cross-dock manager is faced with a strongly resource-constrained workforce. At maximum workforce capacity, the ratio *material handler to dock doors* is typically between 1 to 5 and 1 to 10. Moreover, the cross-dock manager is faced with peaks and troughs in workload – depending on the patterns of (scheduled) trailer arrivals and departures. Transport planners do not set trailer arrival and departure times with the aim to optimize the operations at the cross-dock. We note that, due to driving hour regulations, truck drivers often have to directly dock their trailer upon arrival at the cross-dock. The unloading of that trailer only starts when at least one material handlers is assigned to it. Hence, the main question is how to prioritize the unloading, scanning/checking and movement associated with particular inbound trailers, such that outbound trailer departure deadlines are met.

Another important decision is the assignment of dock doors to trailers. In this cross-dock setting, each dock door is often used both as inbound door (afternoon/early evening) and as outbound door (late evening/nigh/morning). Moreover, the cross-dock setting is characterized by a low ratio of *dock doors to trailers*. It is not uncommon that – on average – each dock door only serves 1 or 2 inbound trailers and 1 or 2 outbound trailers over the full planning horizon. Nonetheless, the strong peaks in trailer arrivals result in situations where many dock doors are occupied at a particular moment in time. Especially during those peaks, there is an important trade-off between docking an inbound trailer at an appropriate dock door with regard to the internal travel distance (e.g., Bartholdi and Gue [2]) and the potential additional costs incurred when waiting for that door to become available. If “the best” door is occupied, but the “second best” is available, it is probably best to dock at the second best one. Yet, when many doors are occupied, the internal travel

distance may increase substantially, which negatively affects material handling efficiency. Alternatively, the trailer is not directly docked (i.e., it waits until an appropriate door becomes available) or the trailer should be decoupled from the tractor and temporarily parking in the yard. In the latter case, a shunting vehicle is needed to dock the trailer. The resources required for the parking and shunting of trailers result in high costs for postponing docking.

3.1.3 Key performance indicators

The main performance indicator for the cross-dock manager is to maximize the throughput rate, which consists of three interrelated components: the size of the *workforce*, the freight *volume* handled, and the *makespan*. The freight volumes are the result of transport planning – and hence cannot be influenced by the cross-dock manager. Similarly, the makespan is largely determined by the planned arrival and departure times of trailers. Accordingly, the primary aim is to maximize the productivity of the workforce – by planning the workforce capacity over time and by assigning material handlers so that operations are performed efficiently.

Another performance indicator is concerned with minimizing the number of shipments that miss their outbound trailer connection and ensuring on-time departure times of outbound line-haul trailers. These performance aspects can either be operationalized as constraints (i.e., shipments may not miss their connection) or as an objective function (i.e., minimize the penalty associated with tardiness of shipments/trailer departures).

3.1.4 Future academic questions

There is a strong need for academic models within the above described context. Except for [7], no models are proposed that simultaneously consider the assignment of dock doors and workforce planning or scheduling. The following primary managerial questions are unaddressed in the literature. What should be the size of the workforce at different moments of the nightly shift? How to allocate material handlers to the different tasks to be performed?

Another promising academic question is concerned with the trade-offs between material handling efficiency (e.g., based on docking trailers at the most appropriate door) and costs incurred for not directly docking a trailer upon arrival. To that end, deriving insights in the characteristics of those waiting costs is strongly needed. In general, considering a broader range of performance indicators – preferably with multiple indicators being considered simultaneously – would contribute greatly to the cross-docking literature.

3.2 LTL break-bulk terminal

In transportation networks, one or multiple LTL break-bulk terminals can be operated to connect – a potentially very large number of – end-of-line terminals. A break-bulk terminal receives inbound trailer loads from its connected end-of-line terminals, which are unloaded, temporarily stored if necessary, and loaded onto outbound trailers returning to their end-of-line terminal. Accordingly, the load factors of the trailers shuttling between

the end-of-line and break-bulk terminals are typically high. In order to limit the additional distribution lead-time associated with the transshipment at the break-bulk terminal, a break-bulk terminal is often operated as a cross-dock.

The description of this typical cross-dock setting is based on a single in-depth case study at the largest break-bulk terminal in a large European pallet distribution network.

3.2.1 Description of logistics processes

The particular break-bulk terminal is located in the United Kingdom. It connects around 150 end-of-line terminals, collectively, carrying between 8.000 and 14.000 pallets from and to the break-bulk terminal each day in 250-400 trailers. Trailers from an end-of-line terminal contain shipments for many other terminals. The typical shipment size is small, i.e., between 1 and 6 pallets per shipment with an average of 1.3. Most end-of-line terminals send two to five trailers that first deliver and then collect pallets at the break-bulk terminal. Operations at the break-bulk terminal mostly take place overnight. A network coordinator, that also owns and operates the break-bulk terminal, developed a long-term plan (i.e., changes only sporadically) specifying the time slots for arriving inbound trailers. The aim of this plan is to spread the number of trailers arriving across the nightly operations. Moreover, the arrival times are based on the distance between the particular end-of-line terminal and the hub – ensuring that even the remote terminals can deliver and collect loads overnight. Similarly, the plan specifies departure times for loaded outbound trailers (i.e., deadlines) such that pallets arrive at their corresponding end-of-line terminal in-time to be delivered by means of next days' routes.

From the perspective of the cross-dock manager, the arrival/departure times of trailers can, in principle, be influenced based on operational cross-dock preferences. We note however, that the extent of this influence is limited for several reasons. Firstly, the arrival/departure times are mostly set to ensure next day delivery of pallets by the end-of-line terminals. Secondly, although the arrival/departure times are set, the load composition of trailers varies strongly every day. These fluctuations are partly due to the lumpy pallet flows and partly to the fact that most end-of-line terminals can dispatch their pallets onto one of multiple trailers bound for the break-bulk terminal.

Inside the cross-dock, one or multiple material handlers unload pallets from a docked inbound trailer. All pallets are placed in the staging area of their corresponding outbound end-of-line terminal. A material handler checks the label to identify its staging area and scans the label to confirm the pallet's arrival. Once all pallets are unloaded from an inbound trailer, the newly-emptied trailer will usually undock and wait until it can be loaded with its outbound pallets. This can occur from the moment sufficient pallets to fill a full truckload have accumulated in the staging area of a particular end-of-line terminal. An outbound trailer is docked closely to its corresponding staging area and loaded by one or multiple material handlers. The loading sequence of outbound trailers is not important as the trailer has only one more stop after departing the break-bulk terminal, i.e., its end-of-line terminal.

3.2.2 Central managerial question

One of the key decisions when managing *break-bulk terminal* cross-dock operations is the sequence in which trailers are unloaded and loaded. The cross-dock manager is faced with a heavily constrained facility in terms of dock doors and floor space available. In the specific cross-dock setting under study, 24 dock doors are available to unload and load 250-400 trailers each night. Hence, each dock door serves between 20 and 34 inbound trailers – and as many outbound trailers. At maximum workforce capacity, each dock door has 2 to 3 material handlers available to facilitate rapid unloading/loading of trailers. The floor space is divided in staging areas such that each of the approximately 150 end-of-line terminals connected to the break-bulk terminal has a dedicated staging area. Roughly, a staging area can contain a bit over one full trailer load. The exact size and location of the staging area depends on the average pallet flows associated with the end-of-line terminal. End-of-line terminals with a relatively large flow have a larger staging area located in the center of the cross-dock.

Inbound trailers form a queue on-site according to their arrival sequence. Generally, inbound trailers are served according to their place in the queue (i.e., FIFO). As inbound trailers are unloaded, the staging areas accumulate pallets for loading onto outbound trailers. Overall, the floor space is far too small to allow all inbound trailers to be unloaded before the loading of outbound trailers start. Therefore, outbound trailers are not only loaded according to their departure deadlines, but also according to the amount of pallets in each staging areas, i.e., nearly overflowing staging areas trigger the loading of a corresponding outbound trailer. The time window for loading an outbound trailer is specified by two boundaries. Loading can only start once sufficient pallets have accumulated and has to occur before there are more pallets than the staging area can hold. A trailer can only be loaded after its inbound loads have been unloaded resulting in new pallets in the staging areas. Clearly, this further complicates the problem of determining the best sequence for serving trailers.

Due to the massive impact of the trailer servicing sequence on operational performance, other cross-dock decisions are considered less important. For example, the assignment of inbound trailers to a specific dock door (for the purpose of minimizing internal travel distance) is not considered a major decision. This is further motivated by the fact that each inbound trailer contains pallets for many different staging areas. The assignment of outbound trailers to dock doors is considered trivial, i.e., always docked closely to its corresponding staging area.

3.2.3 Key performance indicators

The operational performance of the particular cross-dock setting under study is measured primarily according to indicators in two performance domains. The first domain concerns on-time arrival of pallets at their corresponding end-of-line terminals. From the perspective of the cross-dock, this can be ensured by meeting outbound trailer deadlines and minimizing the pallets that miss their outbound trailer connection. Similar to the end-of-line terminal cross-dock setting, these performance aspects can be modelled as constraints or objective functions.

Another important performance domain is related to the utilization of the floor space and material handler safety. Floor space utilization and material handler safety can be realized by minimizing the average or maximum amount of pallets on the floor. This may concern the amount of all pallets on the floor or the amount of pallets in each staging area in particular. Specifically, if the amount of pallets on the floor is minimized, the cross-dock operations can be performed with the limited floor space available even when pallet volumes are increasing. That is, capital intensive investments to expand the floor space can be avoided. Furthermore, a high number of pallets on the floor hinder material handlers in maneuvering through the cross-dock and impede their overview, which increases the chance of accidents.

3.2.4 Future academic questions

Several directions for future cross-docking research follow from the above described *LTL break-bulk terminal* cross-dock setting. At a network level, the characteristics of this setting include the large number of trailers (which are all served first as inbound and then as outbound trailer) from many different end-of-line terminals, the lumpy pallet flows on a disaggregate level (i.e., from one end-of-line terminal to another), and the small-size of typical shipments. At a local cross-dock level, characteristics of this setting include the high dock door to trailer and material handler to dock door ratios as well as the limited floor space available.

To our knowledge, many of the characteristics of the *LTL break-bulk terminal* cross-dock setting are not yet considered in existing literature. Accordingly, future research could consider these aspects in developing decision models supporting the decision that specifies the sequence in which trailers are served at the cross-dock. As discussed above, the optimal, or near-optimal, sequence is mainly determined by the capacity utilization of the staging areas and the outbound trailer departure deadlines. The particular cross-dock under study, would greatly benefit from an on-line decision model that, based on information regarding the loading content of trailers on-site, determines the short-term sequence in which those trailers are best serviced. Such a model could simultaneously consider a *pushing* and a *pulling* force of trailers on-site. That is, inbound trailers or outbound trailers can be *pushed* forward in the sequence as their waiting time at the cross-dock increases, i.e., avoiding excessive waiting time of trailers/pallets on-site. Furthermore, inbound trailers can be *pulled* forward in the sequence when the pallets inside that trailer would complement a full trailer load of pallets readily available in a particular staging area, i.e., rendering the opportunity to clear that staging area. This would be particularly valuable when a corresponding outbound trailer departure is nearly due.

3.3 Retail cross-dock terminal

Whereas the previous two typical cross-dock settings address a many-to-many network configuration; a retail cross-dock is often operated in a few-to-many network configuration. Specifically, each cross-dock terminal is located closely to a group of *many* retail stores –

that are supplied from the particular cross-dock. Most inbound trailers originate from a preceding echelon of a *few* distribution centers and/or a *few* large suppliers.

It is not uncommon for retailers to work with a cross-docking strategy that emerged from opportunistic cross-docking. That is, in the past, intermediate logistics facilities were operated as a distribution center with a large storage facility – where products only bypassed that facility if the opportunity thereto coincidentally appeared. In time, cross-docking evolved into a strategy where the retailer purposely performs its logistics processes such that large volumes are cross-docked. Accordingly, the intermediary logistics facilities have changed into terminals with less storage space and a large dedicated cross-docking area.

The description of this typical cross-dock setting is based on a single in-depth case study at the fresh foods distribution network of a large grocery retailer in The Netherlands.

3.3.1 Description of logistics processes

In the *retail cross-dock terminal* setting under study, the planning of inbound and outbound logistics processes are considered as a part of the overall distribution network planning. The planning of network logistics is primarily aimed at efficiently meeting the service level agreements with retail stores. These service level agreements specify delivery moments such that each store receives its ordered goods within an agreed period of time from ordering. Based on the agreed delivery moments, a central planning department derives time windows for the logistics activities throughout the distribution network – including time windows for arriving/departing trailers at, and operations inside, the cross-dock. Every day, around 150 outbound trailers depart the cross-dock under study. Those trailers carry goods bound for 200 retail stores. As the retailer exerts control over all logistics processes in the distribution network, the operational preferences of the cross-dock can be weighed against the preferences of other logistics processes during the planning of the network logistics.

Inside the cross-dock, the following three freight flows are consolidated. The first flow consists of loads that originate from stock at the warehouse facility inside the same terminal as the cross-dock. This flow constitutes roughly seventy percent of each outbound trailer load. Storage is replenished through a dedicated set of dock doors (i.e., that are not used for the cross-dock operations) and through all dock doors of the terminal when the cross-dock operations are idle, i.e., between 5 PM and 11 PM. The second and third flow originate at the two large national distribution centers – located centrally in The Netherlands – and, collectively, constitute the remaining thirty percent of each outbound trailer load.

Upon arrival, inbound trailers are directly docked. Subsequently, the truck driver unloads the goods from his/her trailer. A team of material handlers takes over the goods and places them in an inbound staging area. The area is used to cluster the goods according to their designated outbound staging area. Once an inbound trailer is fully unloaded and checked for completeness, another team of material handlers starts moving goods to their outbound staging area. At the outbound staging areas, the goods form an assembled outbound trailer load with goods originating from the warehouse facility inside the same

terminal. A dedicated team of material handlers picks those goods from storage – based on orders that are released according to the outbound trailer schedule. Half an hour before the outbound trailer departure deadline, another team of material handlers starts loading the outbound trailer.

3.3.2 Central managerial question

The key decision when managing *retail cross-dock terminal* operations is the assignment of dock doors to inbound and outbound trailers. Similar to the break-bulk terminal cross-dock setting, the cross-dock manager is faced with tight floor space and dock door constraints. In the specific cross-dock setting under study, 31 dock doors are dedicated to serve around 150 outbound trailers and 40-50 inbound trailers carrying loads for the cross-dock operations. These figures indicate a lower dock door to trailer ratio compared to the cross-dock discussed in Sub-Section 3.2. Yet, due to the buildup time required to assemble the outbound trailer loads from local storage, the outbound staging areas (and their corresponding dock doors) are considered strongly resource constrained. As mentioned in Section 3.3.1., timing aspects of assigning dock doors to trailers (i.e., the moment at which trailers arrive at the cross-dock and are served) are determined at a network level.

3.3.3 Key performance indicators

Operational performance of *retail cross-docks* can be measured according to a wide range of indicators. One particularly important local cross-dock performance indicator is derived from a network level performance indicator. At a network level, the retail store delivery service level is a primary performance objective. This network level performance indicator can be translated into local cross-dock constraints specifying that each outbound trailer departs at its pre-specified time and that no goods can miss their outbound trailer connection.

The internal travel distance of material handling equipment – a local cross-dock performance measure well-known in academic literature – is an important indicator for workforce productivity. Other performance indicators are concerned with the volume of goods on-site and the life cycle of cross-docked goods. As inbound trailer loads arrive more and more just-in-time, the life cycle of goods will reduce – as will the maximum and average volume of goods on-site. Accordingly, the utilization of the cross-dock's floor space improves. Improved floor space utilization enables the postponement of costly capacity expansions.

3.3.4 Future academic questions

The cross-dock problems faced in the above retail cross-dock setting are generally in line with the problems described in existing dock door assignment and truck scheduling literature. Nonetheless, the network configuration and resulting freight flow characteristics described above strongly deviate from the problem instances considered in the literature. For example, few academic papers have considered a cross-dock setting with fixed outbound trailer departure times [5] – exceptions are found in [1], [3] and [5]. Moreover, the limited number of origins of inbound trailers (i.e., only two in the illustrative case) and

large number of destinations for outbound trailers (i.e., over two hundred) may affect the solution method to find an optimal, or near-optimal, dock door assignment.

Another difference between the academic state-of-the-art and current practice resides in the performance indicators considered. Whereas most academic papers consider only a single performance measure – typically internal travel distance or the makespan – current practice in retail cross-docking considers a multiple performance indicators from several performance domains. Particularly the just-in-time related performance measures (e.g., regarding the lifespan and volume of goods on-site) are hardly researched. Future research could study the effects of their proposed performance improvement methods on a wide range of indicators – ensuring that improvements in one performance domain do not come at the expense of another.

In retail cross-docking, timing aspects of the dock door assignment are considered an aspect of the distribution network level planning. Rather, academic research has considered these timing aspects under the umbrella of truck scheduling, which is primarily considered a local decision problem. Future research could adopt a network orientation in determining the arrival and departure times of trailers at the cross-dock. That is, departure deadlines for outbound trailers are to be derived from service level agreements downstream in the distribution network. Integrating local cross-dock decision-making and trailer scheduling decision-making at a network level enables the inclusion of actual processing times at the cross-dock in the overall distribution network planning. Accordingly, an interesting question for future research is how such integration can be realized. We note that the realization of alignments in retail cross-dock settings is particularly challenging as also the related warehousing activities play a role.

4. Discussion

Insights from our previous and current cross-docking studies indicate challenging new research problems and a partial mismatch between the recent focus of academic research and the cross-dock settings and problems encountered in practice. An initial comparison between academic and industry perspectives shows differences in two aspects. Firstly, the main difference is found in how the cross-dock's distribution network is considered. In practice, most cross-docks are managed as cost centers, with the sole purpose to enable the consolidation of freight in its distribution network – preferably at the lowest possible additional transportation, facility and holding costs. However, the majority of academic cross-dock optimization studies assume that the tightly related network decisions (e.g., trailer arrival and departure times) can be imposed according to cross-dock operational preferences. In industry, the decision latitude in that regard is often rather limited. Indeed, from a cross-dock perspective, most network decisions are a *fait accompli*. Many cross-docks are, for example, simply confronted with given inbound arrival times and outbound departure deadlines.

Secondly, cross-docking practitioners consider another (and wider) range of performance indicators than typical academic studies. A focus on makespan minimization, which is the most considered objective function in literature [3] [5], is seldom encountered

in practice. Rather, the makespan is often considered fixed and the focus is on minimizing the workforce required to handle the total freight volume within that makespan. A frequently used measure for workforce efficiency is the inner travel distance of material handling equipment [2]. Although useful when determining the layout of a cross-dock, the inner travel distance alone does not fully reflect workforce efficiency at an operational level. Accordingly, in industry, managers often use a range of performance indicators that also reflect the lead time of shipments on-site and the maximum floor capacity needed during the shift. Research including a wider range of cross-dock performance indicators would enable putting the currently used indicators into the context of overall cross-dock performance.

5. Conclusion

This paper describes a comparison between the industry and academic perspectives on cross-docking operations. We describe three typical cross-dock settings based on several in-depth cases at cross-docks in practice. Essentially, cross-docking entails always roughly the same operations, i.e., unloading, sorting/moving, and loading. Nonetheless, this paper shows how key decision problems differ greatly across different cross-dock settings. The network configuration was identified as a critical driver for these differences. Since most academic papers have considered largely similar cross-dock settings, decision problems, and objective functions [3] [5], the detailed descriptions of the typical cross-dock settings in this paper provide ample opportunities for breakthrough innovations in future cross-docking research.

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References

- [1] Acar, K., Yalcin, A., Yankov, D., “Robust door assignment in less-than-truckload terminals,” *Computers and Industrial Engineering* 63, 4, 729-738 (2012).
- [2] Bartholdi, J. J., Gue, K. R., “The best shape for a crossdock,” *Transportation Science* 38, 2, 235-244 (2004).
- [3] Belle, J. van, Valckenaers, P., Cattrysse, D., “Cross-docking: State of the art,” *Omega* 40, 6, 827-846 (2012).
- [4] Belle, J. van., Valckenaers, P., Vanden Berghe, G., Cattrysse, D., “A tabu search approach to the truck scheduling problem with multiple docks and time windows,” *Computers & Industrial Engineering* 66, 4, 818-826 (2013)

- [5] Boysen, N., Fliedner, M., “Cross dock scheduling: Classification, literature review and research agenda,” *Omega* 38, 6, 413-422 (2010).
- [6] Buijs, P., Vis, I. F. A., Carlo, H. J., “Synchronization in cross-docking networks: A research classification and framework,” *European Journal of Operational Research*, in press (2014). <http://dx.doi.org/10.1016/j.ejor.2014.03.012>
- [7] Shakeri, M., Low, M. Y. H., Turner, S. J., Lee, E. W., “A robust two-phase heuristic algorithm for the truck scheduling problem in a resource-constrained crossdock,” *Computers & Operations Research* 39, 11, 2564–2577 (2012).
- [8] Van den Berg, J. P., *Highly Competitive Warehouse Management: An Action Plan for Best-in-Class Performance*, Management Outlook Publishing, The Netherlands (2011).